Popliteal artery volume flow measurement: A new and reliable predictor of early patency after infrainguinal balloon angioplasty and subintimal dissection

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Objective: **We have investigated whether popliteal artery volume flow (PAVF) measured immediately after balloon angioplasties of the superficial femoral artery–popliteal segments (SFA/POP) was predictive of early (30 days) and mid-term (6 months) arterial thrombosis.**

Methods: **During the last 24 months, 203 patients (56% men) with a mean age of 73 ± 9 years had 268 duplex-guided balloon angioplasties of the SFA/POP. Critical ischemia was the indication in 36%. Group I included 176 (66%) with stenoses, and group II had 92 (34%) with occlusions. All patients had completion duplex examinations that included three measurements of PAVF of below-the-knee popliteal artery.**

Results: **Early (30 days) thrombosis of the treated femoropopliteal arterial segment developed in 10 patients (3.7%), three in group I (1.7%) and seven in group II (7.6%; $P < .04$). All 10 cases of early thrombosis were in patients with TransAtlantic Inter-Society Consensus (TASC) class C (6/185, 3.2%) and D (4/26, 15%) lesions. Moreover, the 19% incidence (n = 4) of early thrombosis in patients with PAVF <100 mL/min (mean, 73 ± 24 mL/min; range, 20 to 99 mL/min) was higher compared with the 2.4% rate for patients with higher flows (mean, 176 ± 60 mL/min; range, 100 to 450 mL/min; $P < .01$). At 6 months of follow-up, femoropopliteal occlusions had developed in nine more patients, and it became apparent that low PAVF measurements were still predictive of thrombosis (29%) when compared with higher PAVF cases (6%; $P < .002$). Log-rank comparison of survival curves for cumulative primary stenosis-free patency in group I and group II demonstrated a statistically significant difference ($P < .02$). PAVF <100 mL/min and TASC classification were significant predictors of early (30 days) and mid-term (6 months) arterial thrombosis after femoropopliteal angioplasties. PAVF was the most powerful predictor of arterial thrombosis. The respective 6-month and 12-month limb salvage rates were 98% and 94% for patients with claudication and 88% and 85% for those with limb-threatening ischemia ($P < .0001$).**

Conclusions: **Our results demonstrate that low PAVF is the most powerful predictor of early (30 days) and mid-term (6 months) arterial thrombosis after femoropopliteal interventions. In the presence of a low postprocedure PAVF (<100 mL/min), one may consider not reversing the heparin or using intermittent calf compression, or both, to augment the arterial flow. (J Vasc Surg 2007;45:17-24.)**

The advent of high-resolution duplex imaging has allowed our group to image the vascular tree from the aorta to pedal vessels with sufficient accuracy to plan out the revascularization without the need for additional imaging modalities.[1-5] More recently, we extended this experience to endovascular procedures. Since then, the role of duplex-guided angioplasties in patients with lower extremity ischemia has been an area of great interest at our institution.[6-8]

One of the advantages of using duplex scanning over standard arteriography is the possibility of performing hemodynamic evaluation of the treated arterial segment. Another is the feasibility of measuring volume flows distal to the angioplasty site. It is logical to assume that patients with low volume flow in the below knee popliteal artery after balloon angioplasties of the ipsilateral superficial femoral artery (SFA) are at increased risk of thrombosis compared with patients with higher volume flows. In an attempt to validate this hypothesis, we prospectively evaluated the role of popliteal artery volume flows (PAVF) after angioplasty as a potential predictor of early arterial thrombosis. We also compared several other potential indicators of early success or failure after angioplasty, including the presence of critical limb ischemia, diabetes mellitus, runoff score, and TransAtlantic Inter-Society Consensus (TASC) classification.

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METHODS

Patients. During the last 24 months at our institution, 203 patients had 268 duplex-guided balloon angioplasties of the superficial femoral or popliteal arterial segment, or both, on 226 limbs. The series included 114 men (56%) and 89 women (44%), and their mean age was 73 ± 9 years (range, 42 to 97 years). Concomitant risk factors were hypertension in 160 patients (79%), diabetes mellitus in 99 (49%), smoking in 87 (43%), and coronary artery disease in 79 (39%); in addition, 71 (35%) had elevated serum creatinine levels (≥1.5 mg/dL). Indications for the procedure

were claudication in 172 (64%), rest pain in 17 (6%), ischemic ulcers in 53 (20%), and gangrene in the remaining 26 (10%).

Preoperative evaluation. Preoperative duplex arteriography was performed in all patients by an experienced registered vascular technologists according to a protocol previously published by our group.[1,2] Imaging findings were confirmed by physiologic examinations, including pulse volume recordings and ankle-brachial indices (ABIs). If ABIs were unavailable owing to nonaudible pulses or noncompressible calcified arteries, we recorded ankle tracings amplitude. Duplex arteriography showed a severe stenosis or occlusions, or both, in the superficial femoral artery (SFA) or popliteal artery, or both, in all cases. Group I included 176 cases (66%) with severe arterial stenoses defined as a diameter reduction of ≥70% measured on color or power image and confirmed by a peak systolic velocity step-up of >3. Of these, 127 were primary cases and 49 were restenoses. Group II had 92 cases (34%) with arterial occlusions; 86 of these were primary cases and six were reocclusions. Femoropopliteal lesions were classified using TASC criteria. There were 17 class A lesions (6%), 40 class B (15%), 185 class C (69%), and the remaining 26 (10%) were class D.

An average of 2.2 ± 0.85 patent nondiseased infrapopliteal arteries was found for all patients. There were 126 cases (47%) with all three infrapopliteal arteries patent and without significant stenoses (>50%), 81 (30%) with two arteries, 54 (20%) with one artery, and in the remaining seven (3%), all three arteries were severely diseased or occluded.

Technique. All procedures were duplex-guided balloon angioplasties performed in the operating room using a technique described in previous publications.[6-8] A Philips HDI 5000 duplex scanner with SonoCT feature (Philips Medical Systems, Bothell, Wash) was routinely used. The approach was antegrade through the common femoral artery (CFA) in 242 cases (90%) and through the contralateral CFA in the remaining 26 (10%). Contralateral CFA access required ipsilateral common iliac artery cannulation under fluoroscopy alone in four cases and with 10 mL to 20 mL of contrast in the remaining 22. Visipaque (Amersham Health, Princeton, NJ) was used in 18 cases and Magnevist (Berlex Laboratories, Wayne, NJ) in the remaining four.

Immediately before prepping and draping the patient, we confirmed preoperative duplex findings and marked the stenotic and occlusive arterial lesions on the skin. In addition, we measured PAVF using color duplex imaging and spectral analysis behind the knee three times and recorded an average value. Volume flow was obtained with the Doppler angle adjusted at 60° and the sample volume equal or larger than the arterial lumen. Mean values ± SD and ranges were reported.

A sample of PAVF was recorded three times immediately after completion of the procedure and immediately after the intra-arterial administration of 30 mg of papaverine sulphate. Biplanar scanning of the femoropopliteal arterial segment was performed at the completion of the procedure in all cases. Hemodynamically significant residual defects (plaque dissections and recoils) causing diameter reduction of >30% and a peak systolic velocity ratio of >2 were stented with a variety of self-expandable stents under duplex guidance. Duplex assessment of the tibioperoneal trunk and all three infrapopliteal arteries was performed at the end of the procedure in all cases.

Postprocedure evaluation and follow-up. Arterial duplex pulse volume recordings, including ABIs, were obtained in all patients before hospital discharge and during regular postprocedural follow-up visits in the outpatient office ≤1 month and every 3 months thereafter. Recurrent stenosis was defined as an arterial diameter reduction ≥70% measured by color Doppler imaging and confirmed by a local peak systolic velocity step-up of >3. Arterial occlusion was confirmed by absence of color or power signal in the arterial lumen.

Statistical analysis. Fisher's exact test was used to compare the incidence of low PAVF in group I and group II, incidence of 30 day and 6-month arterial thrombosis for group I and group II, and lower and higher PAVF. The paired *t* test (parametric distribution) was used to compare preprocedure, postprocedure, papaverine-induced PAVF, and ABIs and forefoot pulse volume recording tracings before and after angioplasty. The same analysis was used to compare PAVF for patients with poor (0 to 1 arteries) vs good (2 to 3 arteries) runoff. The statistical software Instat 3.06 (GraphPad Software, San Diego, Calif) for Windows (Microsoft Corp, Redmond, Wash) was used for these calculations.

Arterial patency life tables (Kaplan-Meier survival test and log-rank comparison of the survival curves) for group I and group II, patients with claudication vs patients with critical limb ischemia, and different TASC classified lesions were calculated using GraphPad Prism 4.00 (GraphPad Software). Similar analysis was performed for calculation and comparison of limb salvage rates in patients with claudication and critical limb ischemia.

Multiple linear regression analysis of five potential independent factors contributing to early (30 days) and midterm (6 months) arterial thrombosis, (1) PAVF <100 mL/min, (2) TASC classification, (3) run-off score, (4) critical limb ischemia as an indication for intervention, and (5) presence of diabetes mellitus, was performed using the Unscrambler 9.6 software (CAMO Software Inc, Woodbridge, NJ).

RESULTS

Technical defects and stenting. An average of 1.6 ± 0.9 stents (range, 1 to 5 per case) were placed for treatment of residual lumen defects in 172 (64%) of the 268 cases. The reasons for stenting were plaque recoil in 90 (52%), dissection in 42 (25%), or both in 40 (23%).

Patency rates and limb salvage. The overall cumulative primary stenosis-free patency calculated by life-table analysis for 268 femoropopliteal duplex-guided balloon angioplasties and comparison between stenotic (group I) and occlusive (group II) femoropopliteal lesions is pre-

Table I. Cumulative primary stenosis-free patency calculated by life-table analysis for 268 femoropopliteal duplex-guided balloon angioplasties overall and comparison between stenotic (group I) and occlusive (group II) femoropopliteal lesions

	Group		
Time point	*Overall (%) (n = 268)*	*Group I (%) (n = 176)*	*Group II (%) (n = 92)*
3 months	97	99	89
6 months	83	87	75
12 months	53	55	51

Table II. Comparison of cumulative primary stenosis-free patency calculated by life-table analysis between femoropopliteal duplex-guided balloon angioplasties in 172 cases with claudication vs 96 with critical limb ischemia*

	Indication	
Time point	*Claudication (%) (n = 172)*	*Critical limb ischemia (%) (n = 96)*
3 months	97	88
6 months	88	73
12 months	64	42

*Survival curves were significantly different with $P < .0001$.

sented in Table I. Comparison of cumulative primary stenosis-free patency of patients with claudication vs limb-threatening ischemia is summarized in Table II. Two above knee amputations (0.9%) were performed in the entire series, and both patients (2.5%) were in the group with limb-threatening ischemia. This difference was not statistically significant ($P = .12$). The 12-month limb salvage rate was 94% for patients with claudication, and 85% for those with limb-threatening ischemia ($P < .0001$).

Comparison of preoperative and intraoperative popliteal artery volume flow. The mean preoperative PAVF for all patients was 60 ± 28 mL/min (range, 6 to 149 mL/min). In these patients, the postintervention mean baseline PAVF was 169 ± 65 mL/min (range, 20 to 450 mL/min), an increase that was statistically significant ($P < .001$). All patients demonstrated a PAVF increase after the intra-arterial infusion of 30 mg of papaverine. The mean PAFV increase was 388 ± 213 mL/min (range, 90 to 1350 mL/min), or 134% ± 92% (range, 13% to 567%), which was statistically significant ($P < .001$). However, the increase of PAVF noted after papaverine administration was not a significant predictor of early arterial thrombosis ($P = .30$).

Correlation of arterial patency with postangioplasty popliteal artery volume flow. In 21 (7.8%) of the 268 cases, the baseline mean PAVF was <100 mL/min (mean, 73 ± 24 mL/min; range, 20 to 99 mL/min). Of these, 16 were in the group of 176 transluminal angioplasty cases (9%), and the remaining five (5.4%) were from the 92 subintimal angioplasty cases ($P = .30$). Early (<30 days) thrombosis developed in the treated femoropopliteal arterial segment in 10 patients (3.7%), of which three were from group I (1.7%) and seven (7.6%) were in group II ($P < .04$).

The incidence of early thrombosis was 19% in patients with PAVF <100 mL/min (n = 4) and 2.4% (n = 6) when higher flows were recorded ($P < .01$). At the 6-month follow-up, femoropopliteal occlusions developed in 9 more patients, and it became apparent that low PAVF measurements were still predictive of thrombosis (29%) compared with higher PAVF cases (6%; $P < .002$). Log-rank comparison of survival curves for patency in group I and group II demonstrated a statistically significant difference ($P < .02$).

Correlation of postangioplasty popliteal artery volume flow and primary patency with TASC lesion classification. All 10 cases of early thrombosis were in patients with TASC class C (6/185, 3.2%) or class D (4/26, 15%) lesions. Preoperative and postoperative PAVF for patients classified using TASC criteria are listed in Table III. The correlation of stenosis-free patency with TASC classification for the treated femoropopliteal segments is summarized in Table IV.

Correlation of postangioplasty popliteal artery volume flow and infrapopliteal runoff. Patients with poor runoff (0 to 1 patent arteries) had a mean PAVF of 153 ± 75 mL/min, and patients with better runoff (2 to 3 patent arteries) had a mean PAVF of 173 ± 62 mL/min ($P < .04$).

Multivariate linear regression analysis of factors predictive of postprocedure arterial thrombosis. PAVF <100 mL/min was found to be the most powerful predictor of early (30 days) and mid-term (6 months) arterial thrombosis after femoropopliteal balloon angioplasties. Corresponding data are listed in Table V and Figs 1 and 2.

Adjunctive infrapopliteal angioplasties. Adjunctive infrapopliteal artery angioplasties were required in 49 cases (18%) in this series in an attempt to improve run-off. Of these, 28 (29%) were in the group of 96 patients with critical limb ischemia, and 21 (12%) were in the group of 172 patients with claudication. This difference was statistically significant ($P < .009$). The mean PAVF of 153 ± 64 mL/min in 49 cases with infrapopliteal angioplasties was not significantly different from the mean PAVF of 172 ± 66 mL/min in the remaining 219 cases without infrapopliteal angioplasties ($P = .06$). The comparison of cumulative primary stenosis-free patency rates for patients with and without infrapopliteal angioplasties is presented in Table VI.

Comparison of balloon angioplasties for primary stenoses and restenoses. The mean PAVF was 169 ± 61 mL/min after 127 primary angioplasties and 165 ± 57 mL/min in 49 angioplasties for restenoses ($P = .70$). The mean PAVF was 385 ± 196 mL/min after administration of papaverine in primary angioplasties and 381 ± 217 mL/min in redo angioplasties ($P = .90$). The comparison of cumulative primary stenosis-free patency for patients with angioplasties for primary stenoses and redo angioplasties is represented in Table VII.

Table III. Comparison of preoperative, baseline intraoperative, and papaverine-induced popliteal artery volume flow for 268 femoropopliteal duplex-guided balloon angioplasties classified using TransAtlantic Inter-Society Consensus criteria*

	TASC class			
PAVF (mL/min)	*A (n = 17)*	*B (n = 40)*	*C (n = 185)*	*D (n = 26)*
Preoperative	71 ± 29	61 ± 34	62 ± 26	49 ± 31
Baseline intraoperative	178 ± 77	156 ± 61	169 ± 59	182 ± 102
Papaverine-induced intraoperative	402 ± 330	387 ± 193	385 ± 198	399 ± 260

TASC, TransAtlantic Inter-Society Consensus; *PAVF,* popliteal artery volume flow;
*PAVF was not statistically significantly different for any TASC class lesions at any time point (all $P > .05$).

Table IV. Cumulative primary stenosis-free patency calculated by life-table analysis for 268 femoropopliteal duplex-guided balloon angioplasties classified using TransAtlantic Inter-Society Consensus

	TASC class (n)			
Time point	*A (n = 17)*	*B (n = 40)*	*C (n = 185)*	*D (n = 26)*
3 months (%)	100	94	96	80
6 months (%)	90	81	72	60
12 months (%)	90	62	50	42

TASC, TransAtlantic Inter-Society Consensus.

Table V. Comparison of different factors predictive of early and mid-term* arterial thrombosis after femoropopliteal angioplasty calculated by multivariate linear regression analysis

	P	
Predictive factor	*30 days*	*6 months*
PAVF <100 mL/min	<.00001	<.00001
TASC class	.0016	.0015
Runoff score	.12	.01
Critical limb ischemia	.39	.23
Diabetes mellitus	.15	.84

PAVF, Popliteal artery volume flow; *TASC,* TransAtlantic Inter-Society Consensus.
*Early defined as 30 days, mid-term as 6 months.

Comparison of preoperative and postoperative ankle-brachial indices or pulse-volume recordings. Of the 268 successful angioplasties, reliable ABIs were obtained before and after the procedure in 223 cases (83%). Ankle pulse-volume recordings amplitude tracings were available for comparison in 45 remaining cases (17%). In the latter cases, ABIs were considered unreliable owing to severely calcified noncompressible arteries in 25 or nonaudible pulses in 20.

Overall mean ABIs for the 223 patients were 0.68 ± 0.14 (range, 28 to 0.98) preprocedure and 0.93 ± 0.12 (range, 0.55 to 1.23) postprocedure ($P < .0001$). The mean ankle tracings amplitude was 3 ± 2 mm (range, 0 to 10 mm) before the procedure and 9 ± 4 mm (range, 2 to 21 mm) after for the 45 cases ($P < .0001$). In 203 patients (91%), a significant increase of ABI of ≥0.15 was demonstrated after angioplasty.

DISCUSSION

The results of the present study indicate that PAVF measurements are reliable predictors of early thrombosis after infrainguinal balloon angioplasty and subintimal dissection. Indeed, low-flow PAVF (<100 mL/min) is a more powerful predictor than the number of runoff vessels, TASC classification, presence of diabetes mellitus, or the indication for the procedure. This was observed at 1 month and confirmed at 6 months after the intervention. It is important to emphasize that the data analyzed here specifically evaluate arterial thrombosis and not restenosis.

We have previously shown that increased outflow resistance values measured intraoperatively were reliable predictors of infrainguinal bypass graft success or failure as well as limb salvage. In our previous experience, these measurements were found to be more predictive than the number of patent outflow vessels.[9-17] Thus, it is not surprising that low PAVFs correlated with an increased likelihood of arterial thrombosis after interventions. Other investigators have correlated early failures of angioplasty with distal runoff and degree of ischemia.[18-20] In our data, the number of runoff vessels was only predictive at 6 months after the procedure. Perhaps this criterion may become significant with an increased experience.

Our study is unique in that we confirmed the adequacy of the procedure in all cases by completion duplex scanning examinations. These included visualization of the treated arterial segment and the outflow tract with B-mode, color Doppler, and power-angio, as well as waveform spectral analysis. The latter included measurements of peak systolic velocities and velocity ratios whenever indicated. Accordingly, significant residual stenosis and dissections, as well as distal embolization as potential causes of early thrombosis, were effectively ruled out in all cases.

During this experience, we noted discrepancies between fluoroscopy and duplex guidance for the endovascular procedures.[21] Although angiography provides excellent anatomic details, it is recognized that scant hemodynamic information is obtained. Well-documented drawbacks of contrast-based procedures include misinterpretations of pseudo-occlusions, lack of visualization in the presence of metal prostheses, radiation, nephrotoxicity, and allergy to the contrast me-

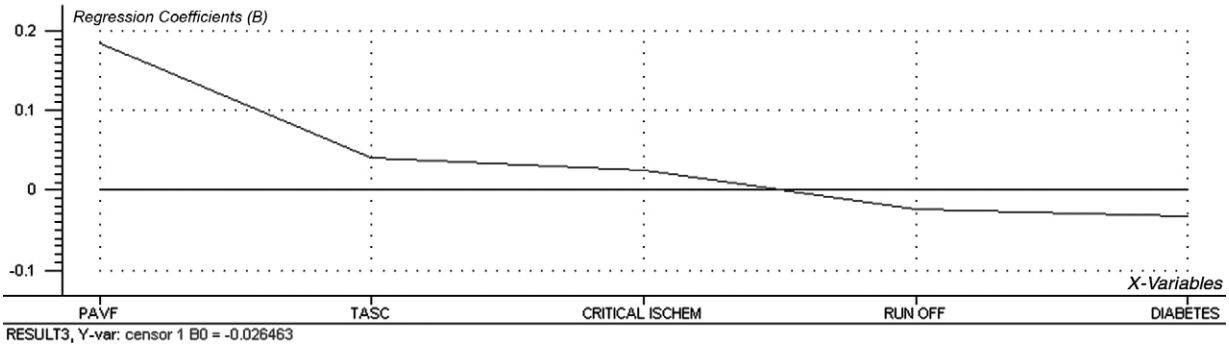

Fig 1. Multivariate linear regression analysis of factors predictive of postprocedure arterial thrombosis at 30 days.

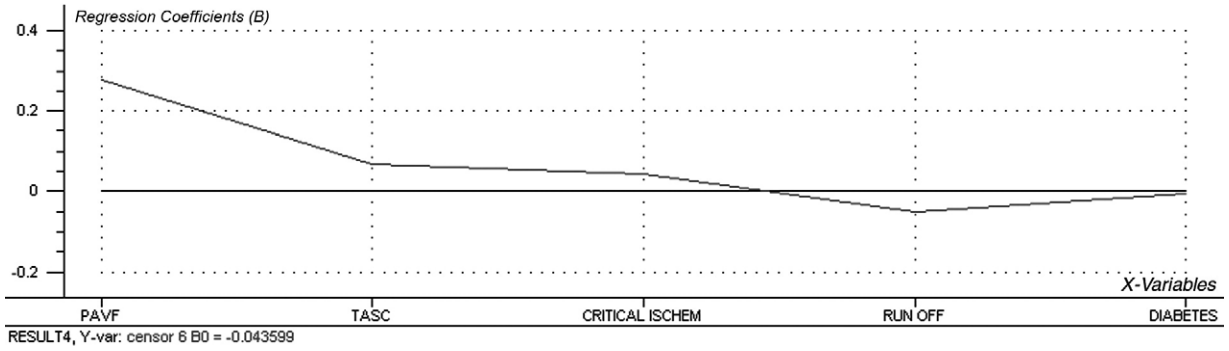

Fig 2. Multivariate linear regression analysis of factors predictive of postprocedure arterial thrombosis at 6 months.

Table VI. Comparison of cumulative primary stenosis-free patency calculated by life-table analysis between 49 cases with adjunct infrapopliteal angioplasties and 219 without infrapopliteal angioplasties*

	Treated segment (n)	
Time point	*Femoropopliteal (n = 219)*	*Femoropopliteal and infrapopliteal (n = 49)*
3 months (%)	96	87
6 months (%)	85	68
12 months (%)	56	34

*Survival curves were statistically significantly different with $P < .02$.

Table VII. Comparison of cumulative primary stenosis-free patency calculated by life-table analysis between 127 cases with primary angioplasties and 49 with angioplasties for restenosis*

	Angioplasties (n)	
Time point	*Primary (n = 127)*	*Restenosis (n = 49)*
3 months (%)	97	93
6 months (%)	79	76
12 months (%)	65	47

*Survival curves were not significantly different, with $P = .08$.

dium. Because hemodynamic information can be obtained with duplex imaging, a high velocity or low volume flow can prompt further examination for a missed defect that may not have been detected by standard arteriography. This is particularly important because biplanar or rotational arteriography is not widely used at the present time to confirm the adequacy of the technique.

Some authors have suggested that routine completion duplex examinations be performed after fluoroscopically guided balloon angioplasty.[22] Because much of the intervention in the fluoroscopic examination is based upon subjective criteria, we suggest that objective indicators be acquired by duplex scanning. For example, a comparison of preoperative and postoperative volume flows offers an objective way to quantitate the effectiveness of the revascularization in the periprocedural period. When an area of borderline stenosis is detected in the SFA, one may choose to rely on volume flows as a guide for reintervention; of course, this needs to be proven with prospective studies. Although prior reports have already determined the feasibility of performing ultrasound-guided interventions,[23-28] our experience suggests that hemodynamic data may provide an additional advantage compared with contrast-based procedures.

We have confirmed the importance of the TASC classification as a reliable predictor of arterial patency after balloon angioplasty[29]; however, this classification was not

as powerful as PAVF in our series. We recognize that causes other than low flow could have influenced these results, including hypercoagulable states, embolization from a more proximal source, or early formation of intimal hyperplasia, or a combination of these. Although these factors were not investigated in the present series, they seem less likely to overcome the predictive power of low PAVF.

The overall major amputation rate of 0.9% in the present series is similar to the rates published in other studies. As expected, this rate was higher for the patients who presented with limb-threatening ischemia (2.5%) compared to the patients with claudication (0%).[29-31]

The question of how to proceed when a low postprocedure volume flow in the popliteal artery is encountered in the absence of significant arterial defects or stenoses is challenging. Several options are possible: (1) consider not reversing the heparin at the end of the procedure, (2) continue anticoagulation for the long-term, (3) use intermittent calf compression to augment the arterial flow,[32] and (4) perform adjunctive balloon angioplasties of the runoff vessels to augment flow in the popliteal artery. These suggestions have not yet been proven, and a larger experience is necessary before this protocol should be implemented.

CONCLUSION

We describe a new predictive factor for early (30 days) and mid-term (6 months) arterial thrombosis after balloon angioplasty of the femoropopliteal segment. As the number of endovascular procedures continues to rise, it is necessary to investigate new variables that can reliably predict the patency of these reconstructions.

AUTHOR CONTRIBUTIONS

Conception and design: EA, AH, NM
Analysis and interpretation: EA, AH, NM
Data collection: AH, NM
Writing the article: EA, AH, NM
Critical revision of the article: EA, AH, NM
Final approval of the article: EA, AH, NM
Statistical analysis: NM
Obtained funding: Not applicable
Overall responsibility: EA

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DISCUSSION

Dr John Blebea (Philadelphia, Pa). There appears to be a big discrepancy between the outcome with subintimal angioplasty versus standard transluminal angioplasty in terms of patency rates. There is also a major decreased patency among those vessels with low flow rate. Were the overall flow rates within the popliteal artery less for the patients undergoing subintimal angioplasty as a group, not just the proportion that thrombosed or had low flows later?

Dr Anil P. Hingorani. No, they weren't. They were actually pretty similar when we looked at the popliteal artery volume flows at the end of the procedure. We were not able to differentiate between these two groups.

Dr Jacob Schneiderman (Tel-Hashomer, Israel). How do you verify that there were no distal emboli related to the procedure? Are you doing any completion evaluation of the distal tree?

Dr Hingorani. As we mentioned before, with the duplex imaging, before the procedure we look at the tibial vessels, and after the procedure we also look at the tibial vessels. With duplex imaging, you can actually see all the way down to the pedal vessels.

Dr Schneiderman. So you feel confident with this ultrasound evaluation to conclude that no emboli went to the distal tree?

Dr Hingorani. We've already had over a thousand patients that we've evaluated preoperatively for open procedures, not only including the femoropopliteal segment but all the way down to the tibials and the pedal vessels, and done bypasses based upon those.

However, the limitations are actually, I think, the key. You don't want to be doing these patients who have very calcified vessels where you can't see what's going on very well. You don't want to be doing this in patients who have a tremendous amount of tissue edema because you're not going to be able to evaluate the vessels well. You don't want to be doing this in patients whose SFA is 6 cm deep, you're not going to be able to visualize and get enough information to do these types of procedures.

Dr Hasan Dosluoglu (Buffalo, NY). I have two quick questions. You have studied a good number of stented patients, so could you identify those who had developed more restenosis, depending on the flow patterns. If you end up with a patient who has suboptimal flow, and you cannot identify why that is, what do you do with these patients?

Dr Hingorani. That second question is actually, I think, one of the more important points. Those types of patients we persistently try to look for an inflow lesion or an outflow lesion. Maybe we missed something on the inflow and we'll go back up and look at the iliac arteries to make sure we didn't miss anything. Unfortunately, we haven't very often found an inflow or an outflow problem. And when you don't, I usually don't reverse the heparin and don't administer the protamine in these types of patients.

In general, we thought we were actually doing okay, because in the recovery room they seemed to be doing all right. But, however, when we looked at them long term, these patients seemed to do much, much worse. They had much higher rates of early thrombosis despite our maneuvers of not reversing the heparin.

We were not actually able to differentiate which patients, even with or without stenting, would have long-term patency based on this data set.

Dr Rumi Faizer (Columbia, Mo). A few questions. First, you must have a good reason why you're using flow volume and not peak velocities and waveforms. And I was wondering how you came to that determination?

Second question. Many of us have been impressed with how you can see a pressure gradient down the SFA and not a clear stenosis on imaging with angio. And I thought that's a wonderful place for this to show itself. I was wondering if you had any correlation between intravascular pressure gradients versus waveforms that you're seeing?

And then, lastly, I was a little bit confused with how you had such a high proportion of TASC C and D lesions, and yet the ABI is averaging 0.68. Why such a discrepancy? I would have expected lower ABIs in this population.

Dr Hingorani. Initially, when you want to try to start doing these types of protocols, you don't want to be doing the TASC Cs and Ds. You want to start off with the thin patient, whose vessels you can easily see, with a short focal stenosis. When you want to start off doing these, we actually suggest that you start doing it preoperatively and not in the operating room, and compare it to angiography for at least the first 25, until you're certain that your results that you're getting from the technologist are greater than 95% accuracy.

We have not compared pressure gradients to these patients. But I think you're actually bringing up one of the clear advantages that other people have already shown in data sets, that duplex imaging, if you take your patient that you did an SFA angioplasty and you immediately do a duplex, you'll find a fair number of lesions that you missed on angiography, even with biplanar angiography, unfortunately. So I think that actually may contribute to one of the reasons why we are stenting a lot more patients as compared to our angiogram patients, because I think we are seeing a lot more lesions that may have been missed. We are seeing a lot more recoil. We are seeing a lot more dissection. We are seeing a lot more residual stenoses that I think we are missing on angiography. But we don't have data comparing it to pressure gradients.

We do use peak systolic velocities routinely. We do use mode B imaging before, after, and during the procedures. This data set right now is just mostly looking at the next step, looking at popliteal artery volume flows.

The average ABIs, I wouldn't be able to say. That's what the numbers were, 0.68. 68% of our patients were claudicants, so I

would not be that surprised if their ABIs were on the order of 0.5, 0.6.

Dr Charles Brantigan (Denver, Colo). Let me change the focus of the discussion for a moment from the technical to the physiologic. The last statement in your conclusions in the abstract says that "Perhaps pharmacological manipulation in this high-risk group of patients may enhance patency rates." I am assuming you are talking about vasodilator therapy of some type. What therapy are you proposing, and for how long are you proposing to use it to enhance the patency rates?

Dr Hingorani. Unfortunately, as you know, the vasodilators have really not really been that helpful. And right now, as I said, all we are doing right now is not reversing the heparin. All of these patients are on Plavix preoperatively and on indefinite aspirin after the procedures. And actually, we are leaving them on Plavix for at least 3 to 6 months after these procedures, irrespective of the popliteal artery volume flows. If we encounter a low popliteal volume flow, we're routinely not reversing heparin, but we are not using any dilators or such.

Dr Brantigan. So you are not actually proposing any different pharmacologic management for the two groups of patients?

Dr Hingorani. Not yet.

Dr Brantigan. Except, perhaps, not reversing the heparin, which many people wouldn't do anyway.

Dr Hingorani. Not yet. I don't think we really have that many alternatives as of yet. That would be a point of discussion and a possible route of further investigation.